EFFECTS OF LIGHT REGIMES ON 1-YEAR-OLD SWEETGUM AND WATER OAK SEEDLINGS

Yanfei Guo, Michael G. Shelton, and Hui Zhang[1]

Abstract—Light regimes vary significantly within small forest openings, ranging from full sunlight to total shade. This may affect establishment, early growth, and competitive status of hardwood seedlings. We used modified shadehouses to simulate light conditions within forest openings and to test the effects of daily photosynthetically active radiation and time of direct light exposure on growth of sweetgum (*Liquidambar styraciflua* L.) and water oak (*Quercus nigra* L.) seedlings. The study was a split-plot design in a completely randomized block layout with four replicates. The five light regime treatments representing the time of exposure to direct sunlight were NO, NOON, MORNING, AFTERNOON, and FULL. Greenhouse-raised sweetgum and water oak seedlings were planted in the treatment plots at a 0.3 x 0.3 meter spacing in early May 2000. Height, groundline diameter, and leaf surface area were determined at the end of the first growing season. Growth for both species generally increased with the amount of direct sunlight received. For treatments receiving some direct sunlight, sweetgum and water oak were the same height at the end of the growing season. However, sweetgum was 35 percent taller than water oak in the fully shaded treatment. For sweetgum, surface area of the average leaf was significantly larger in the fully shaded treatment than in other treatments, but no treatment differences occurred for surface area in water oak. Results suggest that sweetgum seedlings are more adaptive to low light levels than water oak seedlings during the first year of development.

INTRODUCTION

Oak seedlings are shade intolerant to intermediately intolerant and do not grow well under a closed forest canopy (Smith 1992). Once advanced oak reproduction is established, seedlings need adequate light to grow faster than competing vegetation (Minckler 1957, Bey 1964, Sander 1972, Johnson 1979). Light conditions under a canopy can be complex; direct and partial sunlight may reach seedlings during certain times of a day, but seedlings may be fully shaded at other times. A complex light regime with fluctuating periods of direct and indirect sunlight is difficult to mimic but may strongly affect seedling establishment and growth. Gardiner and Hodges (1998) used shadehouses to study the effect of various light conditions on cherrybark oak (*Quercus pagoda* Raf.) seedlings and found that height of 2-year-old seedlings was greatest with 27 and 53 percent of full sunlight. Groundline diameter showed a similar pattern, except that it was greater with 53 percent of full sunlight than with 27 percent. Similar results have been reported by others (Kolb and Steiner 1990a, 1990b; Gottschalk 1994).

Sweetgum (*Liquidambar styraciflua* L.) and water oak (*Q. nigra* L.) are widely distributed in the southeastern United States and have a very similar range (Kormanik 1990; Vozzo 1990). Both species are commercially important within the region. Sweetgum is a rapidly growing, pioneer species while water oak is a medium-sized rapidly growing species. Sweetgum and water oak are potentially major competitors because of their common occurrence. We hypothesized that timing and amount of photosynthetically active radiation (PAR) would affect the growth and characteristics of sweetgum and water oak seedlings. To test this hypothesis, we designed a non-traditional type of shadehouse to simulate the light conditions occurring within small forest openings. Each shadehouse had sections that had no shade cloth on top, which allowed direct sunlight to reach seedlings during different times of day. Applying the methods of Marquis (1965) and Satterlund (1983), we calculated the length of time seedlings were exposed to direct sunlight and tested the hypothesis that the timing and amount of direct sunlight and daily PAR affected seedling growth.

METHODS

The study site was located in Drew County, AR in the West Gulf Coastal Plain. The soil is an Amy silt loam (Typic Ochraquults). Site index for sweetgum and water oak is about 26 meters at 50 years. Before the study was established, the area was an open field, but native vegetation is classified as mixed pines and hardwoods (Larance and others 1976). Annual precipitation averages 134 centimeters, with most occurring in winter and early spring.

The study was a split-plot design in a completely randomized block layout with four replicates. The main plot was exposure to direct sunlight, and subplot was tree species. With the shadehouses oriented toward north, five light regimes were created based on when direct sunlight

[1]Assistant Professor, School of Forest Resources, University of Arkansas-Monticello, Monticello, AR 71656; Research Forester, Southern Research Station, Monticello, AR 71656; and former Graduate Research Assistant, School of Forest Resources, University of Arkansas-Monticello, Monticello, AR 71656, respectively.

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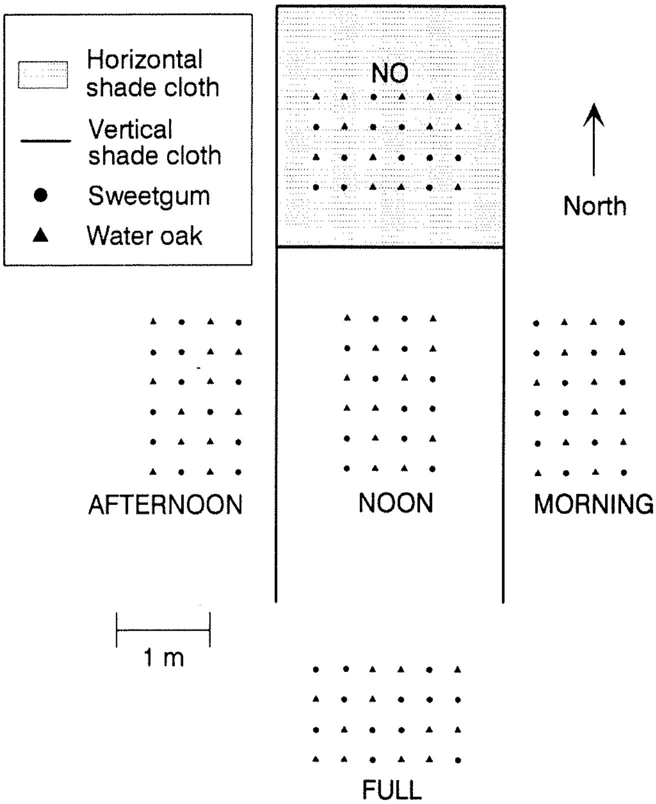

Figure 1—Layout of a modified shadehouse used to create different light regimes for sweetgum and water oak seedlings.

occurred: mostly in the morning (MORNING), around noon (NOON), mostly in the afternoon (AFTERNOON), all day (FULL), and at no time (NO). Shade for the MORNING and AFTERNOON treatments came from the vertical walls (2.4 m tall) of the NOON treatment (figure 1). All shade cloth provided 20 percent of full sunlight. The shadehouse for the NO treatment had shade cloth on the top and all sides except for the lower half of the north side. The NOON treatment only had vertically-oriented shade cloth on the north, east, and west side. The treatments were intended to represent the light conditions occurring within a small forest opening: FULL at the center of a large opening, NO at the south end, MORNING at the western edge, AFTERNOON at the eastern edge, and NOON at the center and northern edge of smaller openings.

Seeds from about 20 open-pollinated trees for each species were collected in Drew County, AR in November 1999, float tested, and stored in a refrigerator at 4 degrees Centigrade. Seeds were stratified for 30 days before germinating in a peat-vermiculite mixture under greenhouse conditions in mid-February. Seedlings were field planted during early May 2000.

Twelve seedlings of each species were planted in each plot with a 0.3 x 0.3 meter spacing in six rows by four columns or four rows by six columns for a total of 480 seedlings in the study. Two seedlings of each species were randomized within each row or column containing four seedlings. During the first month after the planting, we replaced dead seedlings with live seedlings of the same species. Weed-free cloth was used to prevent herbaceous plant competition within the beds. Herbaceous vegetation outside of the beds was periodically controlled with a foliar-applied herbicide. Seedling beds were irrigated to field capacity about weekly from July to September 2000 because of severe drought conditions.

A LI-190SA quantum sensor (LI-COR, Inc. Lincoln, NE) was installed in each treatment of one shadehouse. The calibrated sensors allowed determination of mean PAR for each treatment. PAR was automatically recorded by a LI-1000 data logger (LI-COR, Inc. Lincoln, NE) at a 15-minute interval for 2 days a week beginning in July and ending in early October 2000. The average PAR for each 15-minute interval was calculated for each treatment over the monitoring period, and total daily PAR was computed by adding all the measurements for the average day. Air temperature of one shadehouse was monitored by HOBO Pro Series temperature data loggers (Onset Computer Corporation, Pocasset, MA) throughout the growing season at 5-minute intervals. Temperature sensors were located 30 centimeters above the ground and were protected by white-plastic radiation shields. Soil moisture was monitored by Moisture Point probes (Gabel Corporation, Victoria, Canada) in each bed of all shadehouses. Soil moisture was determined about 7 days after irrigating to field capacity from July to early October 2000.

Seedling height and groundline diameter were measured in October 2000. Forty-eight fully developed leaves from each species and bed were randomly collected, and leaf area and dry weight were determined. Analysis of variance for a split-plot design was conducted on height, groundline diameter, leaf characteristics, and soil moisture using SAS procedure GLM (SAS 1990). Light regime treatments were main effects, and species or soil monitoring depth were subeffects. Replicates for height and diameter were the means for the 12 seedlings of each species in each bed of the four shadehouses, while replicates for leaf characteristics were the means of 48 leaves per species from each bed. Replicates for soil moisture were the means of eight measurements made at a specific depth for each bed from July to early October. Significance was accepted at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The light regimes affected when and how much direct sunlight the seedlings received, and this was reflected in the amount of PAR. The shadehouses created a 3.2-fold difference in PAR across all treatments, and mean daily value was as follows: NO (10), NOON (19), MORNING (27), AFTERNOON (28), and FULL (32 moles per square meter per day). Treatments also differed in mean duration of direct sunlight exposure at ground level from May through October: NO (0.0), NOON (3.4), AFTERNOON (8.5), MORNING (8.4), and FULL (13.0 hours per day).

Air temperature during the day reflected the exposure of beds to direct sunlight (figure 2). In the morning, only the MORNING and FULL treatments received direct sunlight, and this elevated air temperature by 1.0 degree Centigrade over shaded treatments. At noon, all treatments except the NO treatment were in direct sunlight, and air temperature was elevated by an average of 2.4 degrees Centigrade. In

Table 1—Effect of light regime on the mean properties of leaves of sweetgum and water oak seedlings at the end of the first growing season

Direct sunlight exposure	Weight (g/leaf)	Area (cm^2/leaf)	Specific leaf area (cm^2/g)
		Sweetgum	
NO	0.30	59	195
NOON	0.33	48	148
MORNING	0.31	39	125
AFTERNOON	0.31	39	126
FULL	0.35	36	105
		Water oak	
NO	0.11	14	136
NOON	0.14	17	122
MORNING	0.15	16	109
AFTERNOON	0.13	14	106
FULL	0.16	15	99

the afternoon, the FULL and AFTERNOON treatments were the only treatments in direct sunlight, and their temperature was 1.5 degrees Centigrade higher than the treatments in shade.

Water utilization was also affected by exposure to direct sunlight (figure 3). Approximately 7 days after watering to field capacity, volumetric moisture content of the soil was lowest for the FULL treatment and highest for the NO treatment for all monitored depths. Most of the water was apparently transpired because the weed-free cloth and mulch greatly reduced soil evaporation. The differences among light regime treatments and depths were significant for soil moisture (P<0.003) but their interaction was not (P=0.16).

There was no difference in seedling mortality among the treatments, which averaged less than 1 percent for both

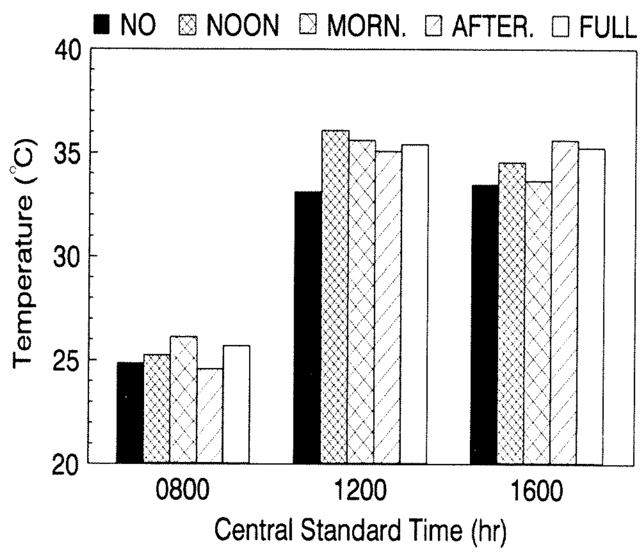

Figure 2—Effects of exposure to direct sunlight on mean air temperature in the morning, at noon, and in the afternoon from July through October.

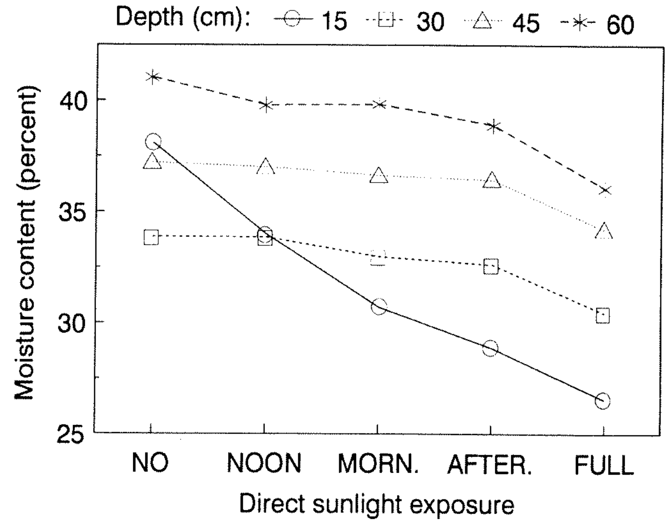

Figure 3—Effects of exposure to direct sunlight on the mean volumetric moisture content of the soil at four monitoring depths approximately 7 days after watering to field capacity from July to early October.

sweetgum and water oak after the termination of replanting. Light regime affected height and groundline diameter for both species (figure 4). There was no difference between the two species for height (P=0.34), but the species differed for diameter (P=0.0001). Light regime and species interacted significantly for height (P=0.03), but did not interact significantly for groundline diameter (P=0.38). Seedling height and groundline diameter of both sweetgum and water oak generally increased with

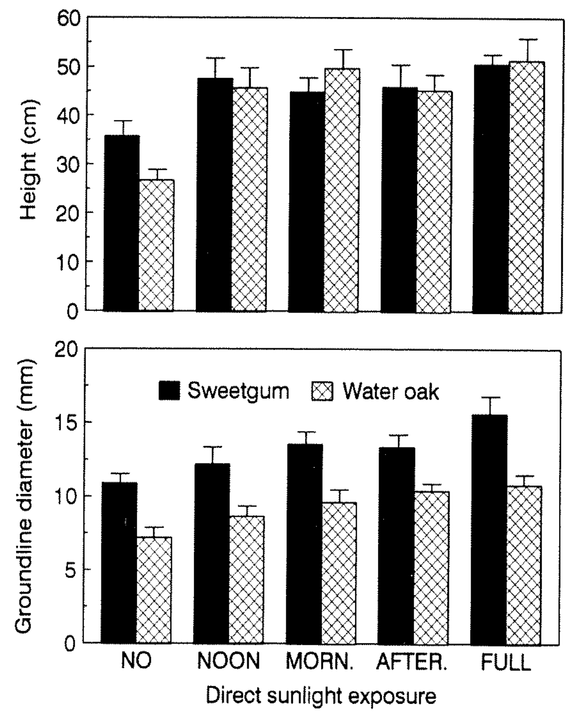

Figure 4—Effects of exposure to direct sunlight on mean height and groundline diameter (plus one standard error) of sweetgum and water oak seedlings at the end of the first growing season.

increasing exposure to direct sunlight. For both species, the most distinctive difference for height was between the NO treatment and the other treatments which received some direct sunlight exposure. With some direct sunlight, there was little difference between the height of sweetgum and water oak, but sweetgum was 35 percent taller than water oak for the NO treatment. Sweetgum consistently had larger groundline diameters than water oak. We observed that water oak would temporarily bend over because of its slender stem when leaves were wet. The difference in height and groundline diameter growth of sweetgum and water oak probably reflects some inherent difference in the early growth pattern of the two species.

Leaf morphology also reflected the differences in exposure to direct sunlight (table 1). For surface area, weight, and specific leaf area (SLA), significant differences occurred for both species and light regime treatments ($P<0.01$). The interaction of species and light regimes was significant for area and SLA ($P=0.0001$) but not for weight ($P=0.74$). The leaves of sweetgum were much larger than those of water oak, by an average of 2.2 times for weight and 2.9 times for area. The SLA of sweetgum and water oak was the same for the FULL treatment (about 100 square centimeters per gram), but the SLA of sweetgum exceeded that of water oak when direct sunlight exposure declined. For the NO treatment, the SLA of sweetgum exceeded that of water oak by 43 percent. Water oak appeared to be less adaptive to reduced exposure of direct sunlight than sweetgum.

CONCLUSION

Although light regime did not affect survival, seedlings exposed to full or partial direct sunlight had higher growth rates during the first growing season than seedlings that did not receive direct sunlight. Thus, the size of forest openings or overstory coverage will be important to provide adequate direct sunlight exposure for seedling development. By producing leaves with a higher SLA, sweetgum appeared to be more adaptive to increasing levels of shade than water oak. Thus, early results of our study suggest that high levels of sunlight are important for water oak to be competitive with sweetgum, especially in early height growth. Since the highest levels of shade occur along the southern edge of small forest openings, this is where water oak will be at a competitive disadvantage with sweetgum. The water-use efficiency was less for treatments receiving high levels of direct sunlight, and the results of our study may have been different had we not controlled competing herbaceous vegetation or provided supplemental water.

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